The Mirror Equation

1) A candle is placed 15 cm from the vertex of a concave mirror that has a focal length of 10 cm.
   a) Locate the position of the image by means of (i) a ray diagram
   (ii) the mirror equation.

$d_o = 15\text{ cm}$, $f = 10\text{ cm}$, $d_i = ?$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$\frac{1}{d_i} = \frac{1}{10\text{cm}} - \frac{1}{15\text{cm}}$

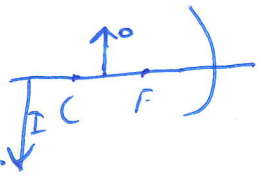
$\left(\frac{1}{d_i}\right)^{-1} = \left(\frac{1}{30\text{ cm}}\right)^{-1}$

$d_i = 30\text{ cm}$

   b) Find the magnification of the image.

$M = \frac{-d_i}{d_o}$ $\quad M = \frac{-30\text{ cm}}{15\text{ cm}}$ $\quad M = -2$

   c) Describe the characteristics of the image.



Inverted, Larger, Real, Beyond C

2) A baby mouse 1.2 cm high is standing 4.0 cm from a converging mirror having a focal length of 300 cm.
   a) Locate the position of the image by means of (i) a ray diagram
   (ii) the mirror equation.

$h_o = 1.2\text{cm}$, $d_o = 4.0\text{cm}$, $f = 300\text{cm}$, $d_i = ?$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$

$\frac{1}{d_i} = \frac{1}{300\text{cm}} - \frac{1}{4.0\text{cm}}$

$\left(\frac{1}{d_i}\right)^{-1} = \left(\frac{-37}{150\text{cm}}\right)^{-1}$

$d_i = \frac{-150\text{ cm}}{37}$

$d_i = -4.1\text{ cm}$

   b) Determine the height of its image.

$\frac{h_i}{h_o} = \frac{-d_i}{d_o}$ $\quad h_i = \frac{-d_i h_o}{d_o}$

$h_i = -\frac{(-4.1\text{ cm})(1.2\text{ cm})}{4.0\text{ cm}}$

$h_i = 1.2\text{ cm}$

3) When a butterfly of body length 4.2 cm is 10 cm from a concave mirror, its image is 15 cm behind the mirror. Calculate
   a) the focal length of the mirror.

$h_o = 4.2\text{cm}$, $d_o = 10\text{ cm}$, $d_i = -15\text{ cm}$, $f = ?$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$\frac{1}{f} = \frac{1}{10\text{cm}} + \frac{1}{-15\text{cm}}$

$\left(\frac{1}{f}\right)^{-1} = \left(\frac{1}{30\text{cm}}\right)^{-1}$

$f = 30\text{cm}$

b) the magnification.

$M = \frac{-d_i}{d_o}$ | $M = \frac{-(-15\,cm)}{10\,cm}$ | $M = +1.5$

c) the length of the image.

$\frac{h_i}{h_o} = \frac{-d_i}{d_o}$ | $h_i = \frac{-d_i h_o}{d_o}$ | $h_i = \frac{-(-15\,cm)(4.2\,cm)}{10\,cm}$ | $h_i = +6.3\,cm$

4) Where must a peanut be placed in order to produce a real image 15 cm from a mirror of focal length 10 cm? What is the magnification?

$d_o = ?$
$d_i = 15\,cm$
$f = 10\,cm$
$M = ?$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$\frac{1}{f} - \frac{1}{d_i} = \frac{1}{d_o}$

$\frac{1}{10\,cm} - \frac{1}{15\,cm} = \frac{1}{d_o}$

$\left(\frac{1}{30\,cm}\right)^{-1} = \left(\frac{1}{d_o}\right)^{-1}$

$30\,cm = d_o$

$M = \frac{-d_i}{d_o}$

$M = \frac{-15\,cm}{30\,cm}$

$M = -0.5$

5) A 60 cm tall red rose is placed 40 cm from a large convex mirror of focal length 20 cm.
a) Locate the position of the image by means of (i) a ray diagram
(ii) the mirror equation.

$h_o = 60\,cm$
$d_o = 40\,cm$
$f = -20\,cm$
$d_i = ?$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$\frac{1}{f} - \frac{1}{d_o} = \frac{1}{d_i}$

$\frac{1}{-20\,cm} - \frac{1}{40\,cm} = \frac{1}{d_i}$

$\left(\frac{-3}{40\,cm}\right)^{-1} = \left(\frac{1}{d_i}\right)^{-1}$

$d_i = \frac{-40\,cm}{3}$

$d_i = -13\,cm$

b) Find the magnification of the image.

$M = \frac{-d_i}{d_o}$ | $M = \frac{-(-13\,cm)}{40\,cm}$ | $M = 0.325$ | $M = 0.3$

c) What is the height of the image?

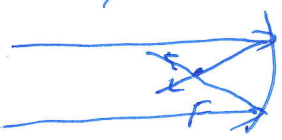
$\frac{h_i}{h_o} = \frac{-d_i}{d_o}$ | $h_i = \frac{-d_i h_o}{d_o}$ | $h_i = \frac{-(-13\,cm)(60\,cm)}{40\,cm}$ | $h_i = 19.5\,cm$ | $h_i = 19\,cm$

d) Describe the characteristics of the image.

Virtual, Upright, Smaller, Behind the mirror (beyond V)

6) Light from the Sun is collected by a concave mirror. How far from the mirror is the image of the star if the radius of curvature is 150 cm? (no, you don't need to know the distance to the Sun; just think about it, and explain your reasoning)

- star is so far away light comes in parallel to mirror

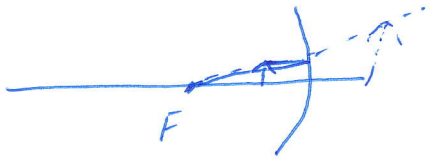


- will all reflect through F
→ Image on (75 cm) F

7) A production line inspector wants a mirror that produces an upright image with magnification of 7.5 when it is located 1.40 cm from a machine part.

a) What kind of mirror would do this job?

Concave



$M = 7.5$
$d_o = 1.4\text{cm}$

b) What is its radius of curvature?

$R = ?$
$M = -\frac{d_i}{d_o}$
$d_o M = -d_i$
$d_i = -(1.4\text{cm})(7.5)$
$d_i = -10.5\text{ cm}$
$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$
$\frac{1}{f} = \frac{1}{1.4\text{cm}} + \frac{1}{-10.5\text{cm}}$
$\left(\frac{1}{f}\right)^{-1} = \left(\frac{13}{21}\right)^{-1}$
$f = \frac{21\text{cm}}{13}$
$f = 1.6\text{ cm}$
$R = 2f$
$R = 2(1.6\text{cm})$
$R = 3.2\text{cm}$

8) A mirror produces an erect, virtual image of an object. What type of mirror would this be? (hint: there is more than one possible answer here)

- plane mirror
- convex mirror
- concave mirror if object between f and V

9) How far would an object need to be placed from a mirror of focal length 10.0 cm if it is to produce an image which is 20.0 cm BEHIND the mirror?

$f = 10.0\text{cm}$
$d_i = -20.0\text{cm}$
$d_o = ?$
$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$
$\frac{1}{f} - \frac{1}{d_i} = \frac{1}{d_o}$
$\frac{1}{10.0\text{cm}} - \frac{1}{-20.0\text{cm}} = \frac{1}{d_o}$
$\left(\frac{3}{20\text{cm}}\right)^{-1} = \left(\frac{1}{d_o}\right)^{-1}$
$d_o = \frac{20\text{cm}}{3}$
$d_o = 6.67\text{ cm}$

10) A mirror with a focal length of -100.0 cm is used to form an image. An object is placed 50.0 cm in front of the mirror. a) Where is the image located? b) What type of mirror is being used in this problem?

a) $f = -100.0\text{cm}$
$d_o = 50.0\text{cm}$
$d_i = ?$
$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$
$\frac{1}{f} - \frac{1}{d_o} = \frac{1}{d_i}$
$\frac{1}{-100.0\text{cm}} - \frac{1}{50.0\text{cm}} = \frac{1}{d_i}$
$\left(\frac{-3}{100\text{cm}}\right)^{-1} = \left(\frac{1}{d_i}\right)^{-1}$
$-33.3\text{ cm} = d_i$

b) Convex (negative f)